

## Space Systems Environmental Interaction Studies

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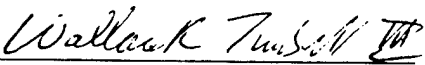


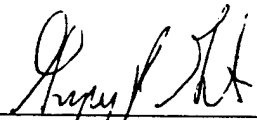
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13. ABSTRACT (Maximum 200 words) Final system testing, performance characterization and documentation of the Digital Ion Drift Meter (DIDM-2) instrument were carried out in the period immediately prior to delivery, which transpired under Task #1 of this contract. Some details of these activities are provided. Also, a summary of the activities performed under Task #2, with regard to the SPREE and OEDIPUS-C data sets, is also presented. The work was terminated in this report period. The principal focus of this report however, is to document the operation and functionality of DIDM-2. The material is excerpted from the instrument's Handbook of Commands, Functions & Operations manual.				
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## 1. INTRODUCTION

This contract's objective is to further the understanding of near-earth environmental dynamics, by conducting both *in situ* experimental studies, as well as, analytical and empirical studies of returned instrument data. The work is to be accomplished through three programs, subsequently identified as Task #'s 1, 2 and 3. A brief review of the scope of each program and a summary of the work performed during the report period follows. The material is presented in serial order, with Task #1 issues appearing first in Section 2.

## 2. TASK #1—DIDM EFFORTS

### 2.1 Program Definition

The objectives of this task are two-fold. They are: (1) develop the means to reliably measure ion densities in the range of  $10^1 \text{ cm}^{-3}$  to  $10^7 \text{ cm}^{-3}$ , by using digital rather than analog techniques, and thereby extend the existing dynamic range for such measurements by at least three orders of magnitude. (2) determine the incident angle of ions into the instrument within  $3^\circ$  in two dimensions, to allow accurate determination of ion drift velocities.

The work performed during the report period falls within Phase 3 of this task, and is a continuation of the effort to provide a Digital Ion Drift Meter (DIDM-2) instrument for AFRL to deliver to the German research organization GeoForschungsZentrum (GFZ), for inclusion in their earth studies research satellite CHALLENGING Minisatellite Payload (CHAMP) instrument suite. DIDM will be integral to the global earth magnetic and electric field mapping aspect of the CHAMP mission.

### 2.2 Summary of Activities

The report period was an event filled one, with regard to DIDM-2 activities. The principal focus was on completing various tasks in order to meet the final instrument delivery date (which was changed on more than one occasion). But evaluating and documenting the as-built specifics of the hardware in a Handbook of Commands, Functions & Operations manual occupied a large portion of time as well. Of significance also was the preparation for and presentations given at the Comprehensive Flight Readiness Review (CFRR), which was convened immediately prior to final flight instrument delivery, at AFRL—Hanscom AFB, by GFZ. The proceedings were a forum to answer outstanding questions pertaining to instrument performance (event detect timing and dead times in particular), as well as a briefing to the review board on the instrument's development chronology, including details of the problems encountered and how they were overcome. Shortly after the successfully concluded review, the instrument was handed over to AFRL for delivery to Germany and installation on the CHAMP spacecraft.

### 2.3 The DIDM-2 Instrument

The following material is excerpted from the DIDM-2 Handbook, which is a compilation of information on the operation and functionality of the instrument. The as-built state of DIDM-2 is documented in the Handbook, and it will also be the final reference for on-orbit operations of the instrument, especially during investigations of non-nominal events.

#### 2.3.1 Power

DIDM-2 consumes 4.76 W (0.170 A) at +28 V, when high voltage is *OFF*. The power draw increases to 5.04 W (0.180 A) after *HV-ON* is enabled and the instrument is in its highest power draw



mode. The turn *ON* inrush current was measured to be 2.0 A max. in 500  $\mu$ s, after integration on the spacecraft. It is reduced to the nominal current draw in 7.0 ms.

### 2.3.2 Over-Current Protection

The primary power lines on CHAMP will be protected by means of latching current limiters (LCL), which will provide the current limiting characteristic as depicted in Figure 1. The specification on LCL performance is as follows:

- The LCL will provide command resettable overcurrent protection. After tripping no automatic reset shall be performed.
- The LCL will limit inrush currents to 2 A for 50 msec with a tolerance of  $\pm 10\%$  for both time and current.
- The payload interface controller will monitor the current of the LCL outlet in time intervals of 100 msec, and switch it off when the software current limit of 0.35 A is being permanently exceeded during 10 intervals (i.e. 1 second period).

DIDM-2 performance has been tested for various input voltage and current limits. The instrument initializes nominally with a current limit of 1.8 A, for input voltages between +32 V to +18 V. At +18 V, the instrument initializes nominally with a current limit as low as 0.66 A.

### 2.3.3 Serial Interface

The CHAMP spacecraft uses a RS-422 asynchronous serial interface for communication between the On-Board Data Handler (OBDH) controller on the spacecraft and DIDM-2. Communication between the OBDH and the DIDM-2 uses the following line protocol mode: 19200 baud, 1 start bit, 8 data bits (LSB first), no parity, 1 stop bit.

#### 2.3.3.1 Telemetry Transfer Sequence

The OBDH acts as the master in communication between DIDM and CHAMP. This means that data is only sent to the OBDH if DIDM-2 is enabled by the OBDH to send. The enable mechanism uses a single H/W handshake line (RTS/CTS protocol). The OBDH TxD (output) lines will be used to transmit command messages to DIDM-2 and the OBDH RxD (input) lines will be used to receive instrument data. To request an instrument to send its next data block, the OBDH will activate the RTS line. DIDM-2 will then start transmission of its next block of data. When the OBDH deactivates the RTS line, DIDM-2 stops further data transmission, regardless of whether or not there is still data to be sent.

Command messages sent by the OBDH and HK/science data received by the OBDH from DIDM-2 shall be transmitted in continuous blocks without time delays between the bytes of a block.

#### 2.3.3.2 Data Rate

The maximum line speed for data transfer to CHAMP is specified to be 1920 bytes/sec (19,200 baud for 10-bit period). Although there are possible mode configurations for DIDM-2 that would result in a maximum output rate of 2690 bytes/sec, the instrument is limited to a maximum of 1345 bytes/sec. The nominal allocation for DIDM-2 data is for an average of 1500 bits/sec ( $\approx 187$  bytes/sec), per orbit. The maximum burst rate permitted is 5000 bits/sec ( $\approx 625$  bytes/sec). Both of these numbers are exclusive of overhead such as headers, timestamp, start and stop bits, etc. Proper care must therefore be taken when commanding the instrument to ensure that the burst-rate limitation is not exceeded in the set configuration.

### 2.3.4 Instrument Timing & Operations

All DIDM-2 operations are synchronized with the 1 Hz sync pulse from CHAMP. In the absence of this signal, the instrument will pause operations and wait indefinitely for it to return. Output data is double buffered in DIDM-2. The sync pulse is used to initiate the one-second period in which data is acquired for the output telemetry, and to create a telemetry frame from the previous second's data. DIDM's one second data-taking frame starts 31.25 ms after the sync pulse, and ends 31.25 ms after the following sync pulse. Sync pulse spacing of more than the nominal 1000 ms has no impact on instrument operation, other than to extend some accumulation intervals. Sync pulse spacing of less than 985 ms may cause DIDM to skip some data taking, and may result in data from a previous acquisition period appearing in the current telemetry frame.

**Notes** (i) There is a *SYNC EARLY* bit in the *Status* data packet, which tells if a Sync pulse spacing of less than 985 ms was detected by the instrument.

#### 2.3.4.1 Timing Relationship for Telemetry Frame and Data-Taking Frame

Generally, data that is sampled in a one second data-taking frame is telemetered one second after that data-taking frame ends (two seconds after it starts). The data taking /telemetry relationship is illustrated in Figure 3. Exceptions to this rule occur with: (i) PLP data (which is acquired at two different sample rates and is buffered to distribute the data across multiple telemetry frames). (ii) Background Image data (an entire Drift Meter image is buffered, then depending on configuration, takes 2, 4, 8, 16 or 32 seconds to telemeter).

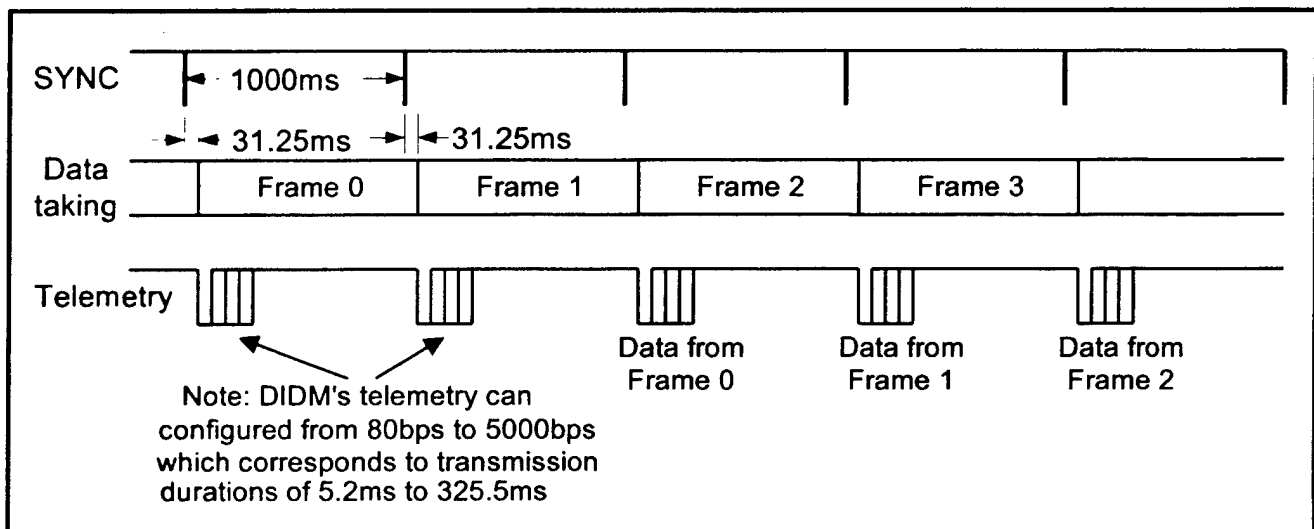


FIGURE 1: DIDM-2 DATA-TAKING/TELEMETRY RELATIONSHIP

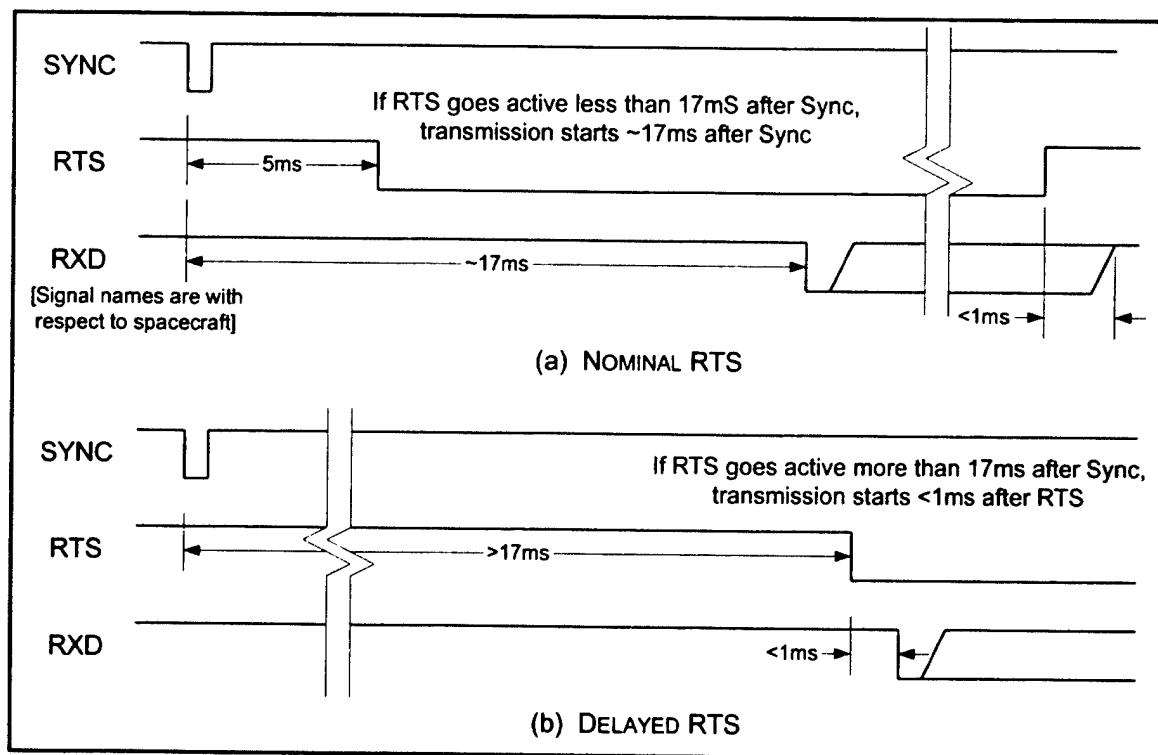


FIGURE 2: DIDM-2 TIMING RESPONSE TO: (a) NOMINAL; (b) DELAYED CHAMP RTS HANDSHAKING SIGNAL

When *RTS* is active, DIDM-2 will start transmitting a telemetry frame about 17ms after the active edge of the sync pulse. If *RTS* is not active, the instrument will wait for it to go active before transmission starts. If *RTS* goes inactive during a transmission sequence, DIDM-2 will complete the byte that is been transmitted, and will likely send one more byte before transmission is stopped (although this is not guaranteed). DIDM-2 will resume its transmissions if *RTS* again goes active. In any case, only the most recent telemetry frame is transmitted.

**Notes** (i) Data is assembled for output, simultaneous with the acquisition of new data. Therefore the first data packet after the temporary loss of the *Sync* or *RTS* signals, will not always be valid. In fact it was observed during the flight unit checkout that first packet varies in size and timing. Assuming that *Sync* and *RTS* will not be interrupted very often, the occasional loss of a data packet here is not thought to be critical.

#### 2.3.4.2 Software Induced Dead Times

Since many of the processor's tasks are coincident with the start of accumulation periods, the accumulation periods may be shortened from their nominal values. It is necessary for the processor to disable the DSP section when any sensor information is read (RPA counts, image counts, gate counts, etc) to guarantee that the data is stable during readout. Servicing an RPA is fast (<50μs) and can probably be ignored, as it changes the shortest accumulation period (62.5ms) by less than 0.1%. But processing the Drift Meter packets and image packets can have a measurable effect. The following times were measured on the DIDM prototype, running the flight code:

Generating a 'small stencil':	~ 400 μs
Generating a 'large stencil':	~ 1 ms
DM packet for Rp=15 :	~ 1.60 m s
DM packet for Rp=14:	~ 1.70 m s
DM packet for Rp=13:	~ 1.75 m s

DM packet for Rp=12:	~ 1.85 ms
DM packet for Rp=11:	~ 1.90 ms
DM packet for Rp=10:	~ 1.95 ms
DM packet for Rp=9:	~ 2.00 ms
DM packet for Rp=8:	~ 2.05 ms
DM packet for Rp=7:	~ 2.15 ms
DM packet for Rp=6:	~ 2.30 ms
DM packet for Rp=5:	~ 2.50 ms
DM packet for Rp=4:	~ 2.90 ms
DM packet for Rp=3:	~ 3.25 ms
DM packet for Rp=2:	~ 3.45 ms
DM packet for Rp=1:	~ 3.60 ms
DM packet for Rp=0:	~ 3.60 ms

In addition, when Background Image packets are selected, the instrument periodically reads out the entire DM image to buffer it for the construction of background packets. 2048 pixels per array / 64 pixels per BG packet = 32 background packets to send the entire image. So, depending on the number of BG packets being telemetered each second (1, 2, 4, 8), the image is buffered every 32, 16, 8 or 4 seconds. Again, using the DIDM prototype with the flight code, the following was measured:

Refresh of Background image buffer 1.55 ms

**Notes** (i) Since the DSP section is common to both sensors, *all the software-induced dead times apply to the accumulation times for both sensors, and apply to the accumulation following the one for which the dead time is calculated.* [All of these software procedures are executed after an accumulation is complete, and thus delay the start of the following accumulation.]

Example: DM A = 8 Hz; DM B = 8 Hz; no image packets; the DM packet for A reports Rp = 10 and the corresponding DM packet for B reports Rp = 6. 1.95 ms + 2.30 ms = 4.25 ms. Thus, the following accumulation for both A & B would be delayed by 4.25 ms, giving an actual accumulation period of 125 ms - 4.25 ms = 120.75 ms, a 3.4% error.

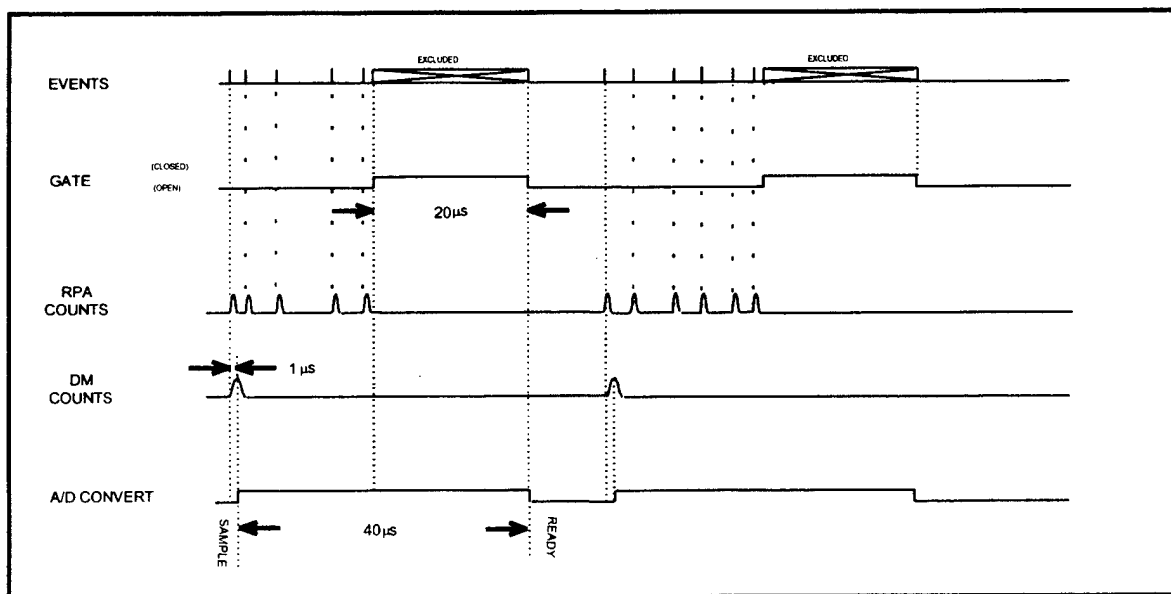


FIGURE 3: INCIDENT PARTICLE EVENTS - GATING & CONVERSIONS

### 2.3.4.3 Incident Particle Events – Gating & Conversions

DIDM-2 utilizes an asynchronous gating scheme to control the number of incident particles into the sensors. The process is not periodic, but is driven by the detection of the first valid event, after it is possible to do so. A timing schematic is shown in Figure 3. Also indicated is the relationship between incident events and the conversion to RPA and DM counts. It is seen that for 20  $\mu$ s after the first event is detected, the gate remains open. All subsequent events in this period are registered as RPA counts. Then the gate is closed for the next 20  $\mu$ s, after which it opens automatically. On the other hand, a DM count is only registered for the first valid event detected. Furthermore, in order to properly process the DM count signal and implement the necessary pixel binning algorithms, another DM count is precluded for at least 40  $\mu$ s after the previous. This is represented by the 40 ms *A/D CONVERT* signal.

#### 2.3.4.3.1 Anode Signals and Event Binning

For an incident particle that impacts the MCP and triggers a response on the wedge & strip anode, the event detection process can be described as follows: Events that produce a sum signal below the '*lower threshold*' (which is the lowest detection threshold in the hardware) are rejected. All events above the lower threshold are counted as RPA counts. The very first event (e1) also increments the Gate count and initiates the process whereby the Gate is closed 20  $\mu$ s later. The Gate will remain closed for an additional 20  $\mu$ s, after which it opens automatically. In the 20  $\mu$ s interval it is open, additional events above the lower threshold are counted as RPA events only. If e1 is above the lower threshold but below a '*resolving threshold*' it is also counted as a DM count but assigned to pixel (r15, c127), which is the '*reserved pixel*'. If e1 is between the resolving threshold and an '*upper threshold*' it is resolved into a normal DM pixel address and accumulated as valid image event. If e1 is above the upper threshold, it is still counted as both an RPA and Gate count, but NOT as a DM event because of electronics saturation concerns.

Specific details are as follows:

- (1) There is a minimum amplitude [Lower Threshold] for the sum signal of an event, below which nothing is triggered; i.e. no RPA, Gate, or DM event. The measured voltage level is 0.320V. This setting is a compromise between maximizing detection sensitivity and rejecting electronic noise.
- (2) Immediately above this minimum amplitude, RPA counts and Gate counts (for the first event only), are both triggered. But signal amplitudes are low enough that the DSP doesn't have adequate resolution to perform accurate ratios and provide a valid DM count. Such events, with the sum amplitude higher than the minimum amplitude but below the resolvable amplitude go into the reserved pixel (r15, c127). Since the DSP doesn't resolve events with lower signal amplitudes, let's call this the [Resolving Threshold].
- (3) Immediately above the resolvable amplitude, RPA counts, as well as Gate and DM counts (for the first event only), are triggered, until signal levels reach approx. 3.50V [Upper Threshold]. Above this amplitude, event signals are again rejected as valid DM events. There is no direct indicator for events that are above the Upper Threshold for DM image selection. This value has to be deduced from those returned for Gate Count and DM Count, on a per second basis. Nominally, Gate Counts should equal DM Counts. Since counts below the Resolving Threshold are included in both Gate counts and DM counts (via the reserved pixel), the difference between Gate counts and DM counts is due only to above Upper Threshold events.

A simplified reason for the Upper Threshold limit is to guarantee that signal amplitudes are within the input range of analog/digital converter (ADC). If the amplitudes went beyond the input range,

aliasing would occur (i.e. the measured value would roll over). The Upper Threshold prevents this from happening.

#### 2.3.4.4 Timing Details for Drift Meter Measurements

A comprehensive timing diagram in which all the timing details pertaining to Drift Meter measurements are shown is presented in Figure 4. Details for all five DM sampling rates (1 Hz, 2 Hz, 4 Hz, 8 Hz, 16 Hz) are given. Included as well are the best and worst dead times for each sample.

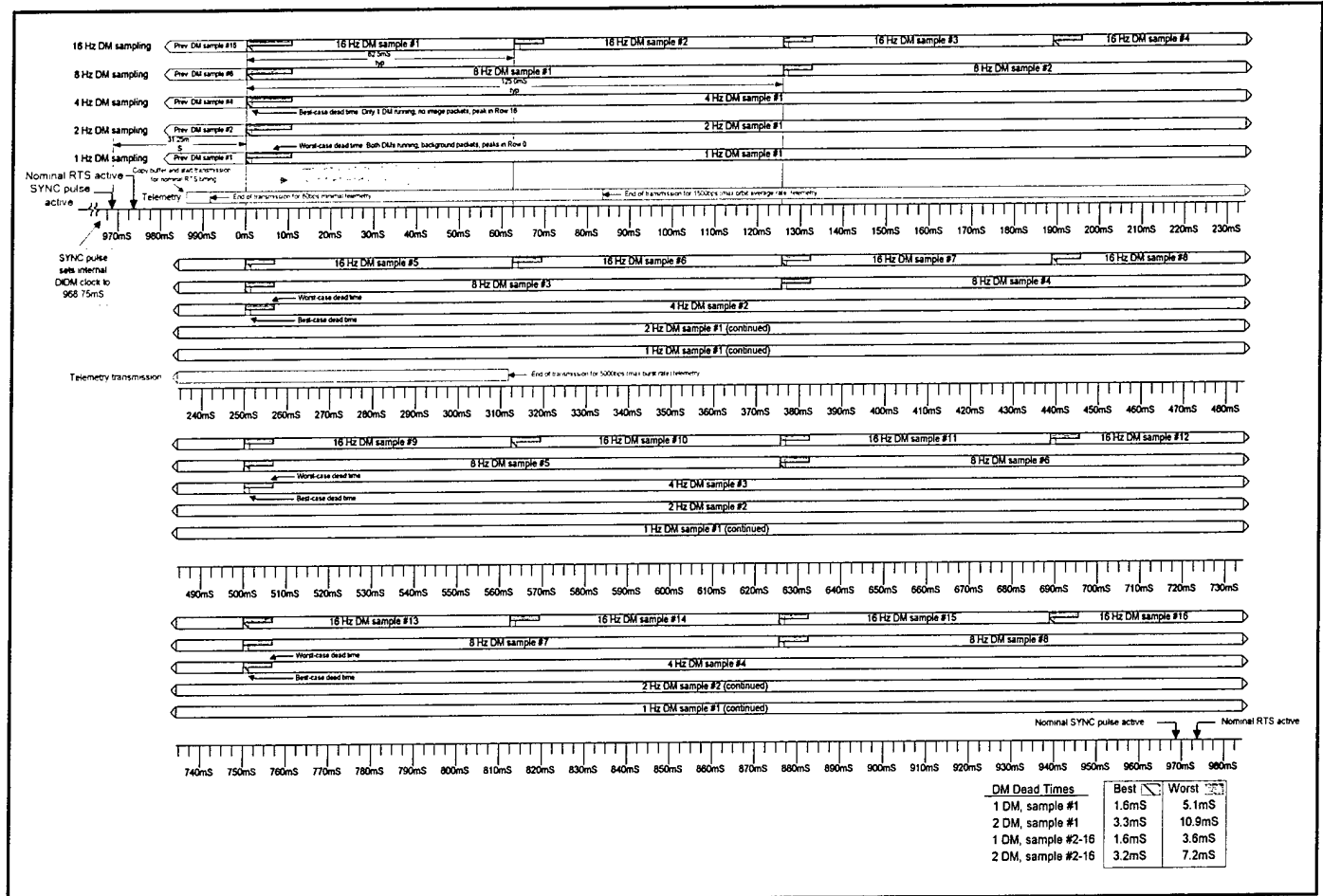


FIGURE 4: TIMING DETAILS FOR DRIFT METER MEASUREMENTS

### 2.3.4.5 Timing Details for RPA Measurements

A comprehensive timing diagram, in which all the timing details pertaining to RPA measurements are shown is presented in Figure 5. Details for the two DM sampling rates (8 Hz, 16 Hz) are given. Included as well are the best and worst Dead Times for each sample.

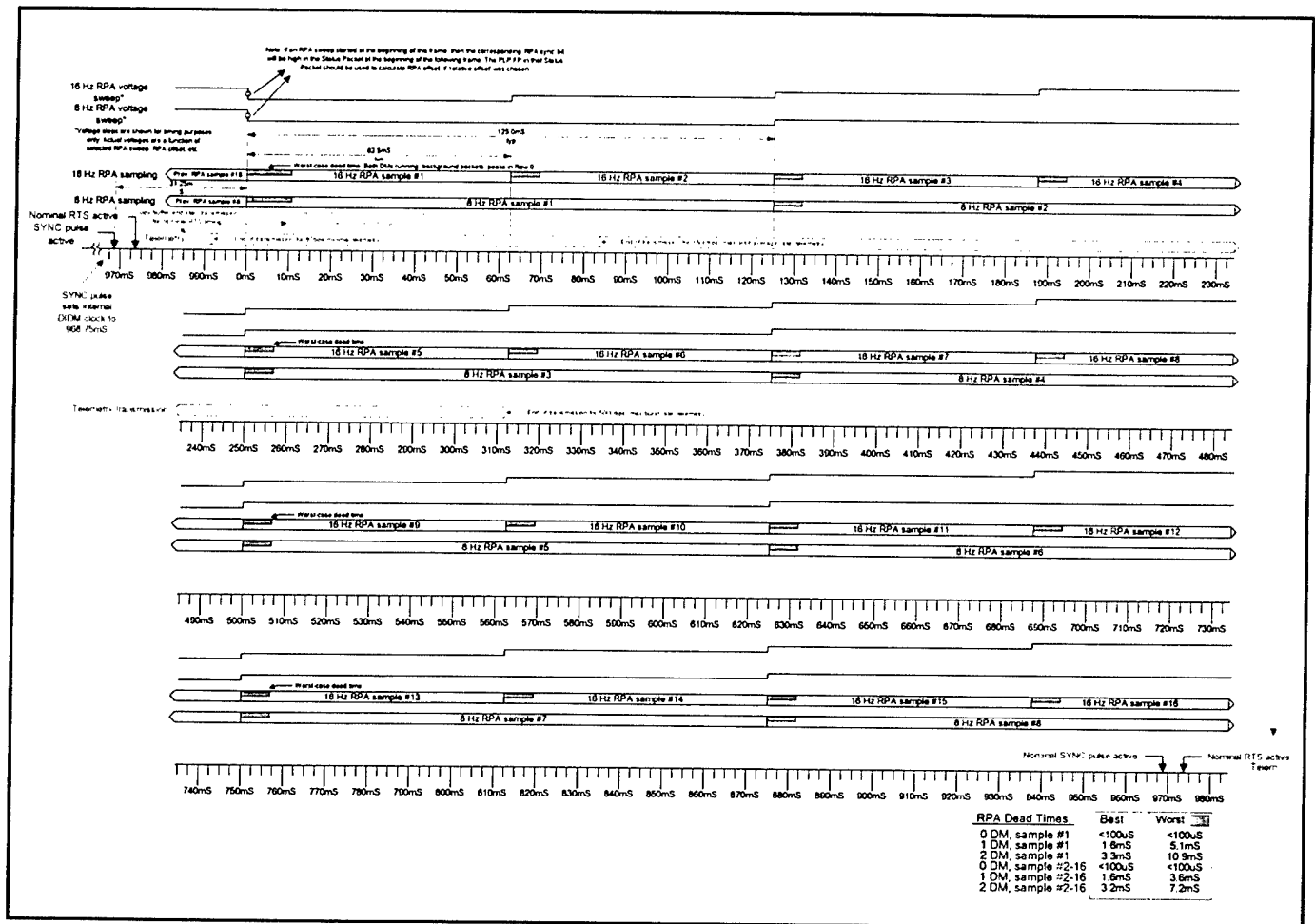


FIGURE 5: TIMING DETAILS FOR RPA MEASUREMENTS

### 2.3.4.6 Timing Details for PLP Measurements

A comprehensive timing diagram, in which all the timing details pertaining to the one-second electrometer measurements of the PLP are shown, is presented in Figure 6.

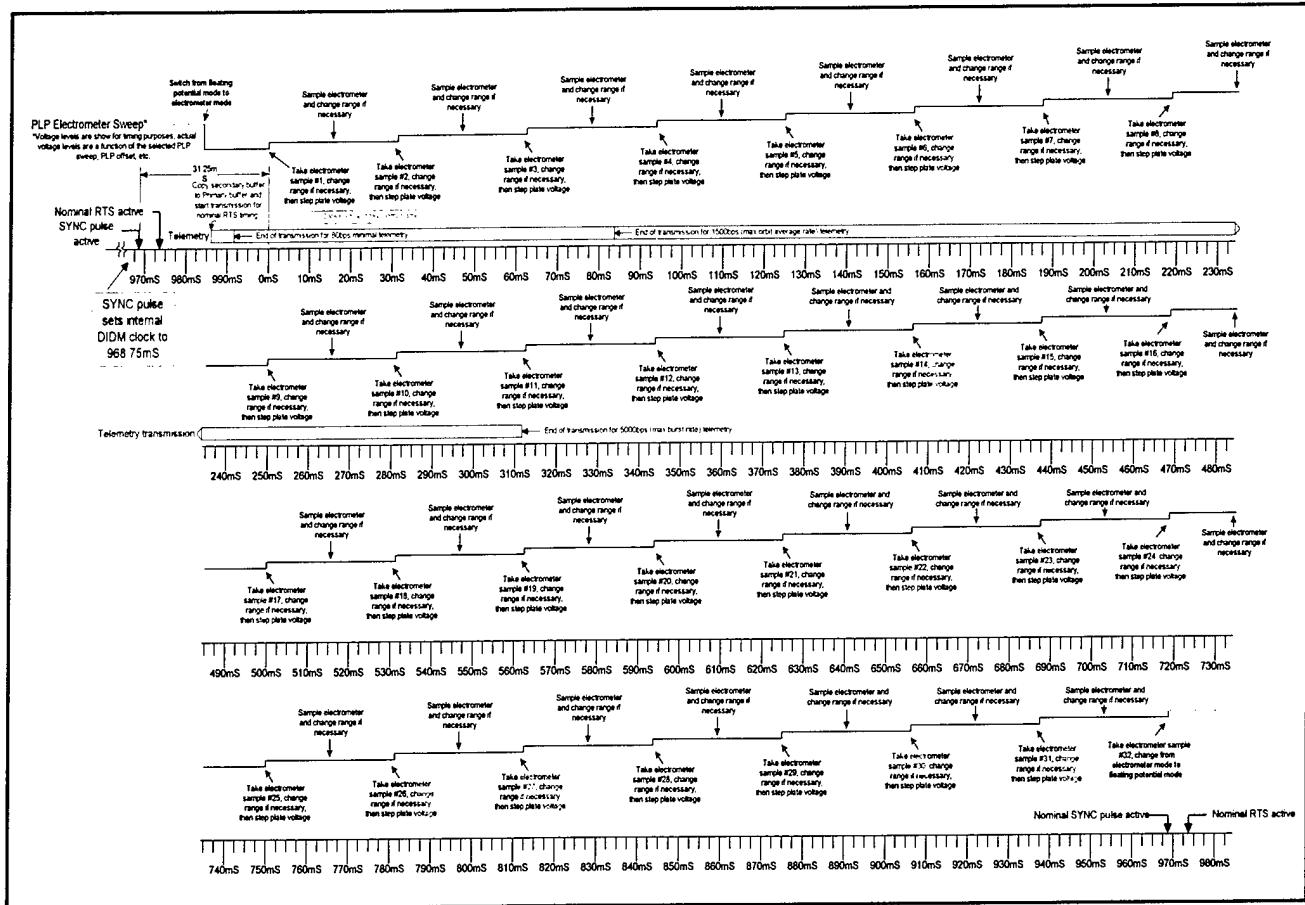


FIGURE 6: TIMING DETAILS FOR PLP MEASUREMENTS



### 2.3.5 Commands

The operation of the instrument is controlled through the use of its configuration library and operations mode stack. The library has 8 read-only configurations and 8 slots for configurations uploaded with the *Configuration Define* command. The mode stack has 16 slots that contain both a configuration and a duration. The *Configuration Select* command loads selected configurations from the library to the mode stack and sets the duration. DIDM-2 then moves from the top of the stack to the bottom in sequence, dwelling on each mode for the required duration. A duration of zero is the indication to return to top of the stack. The maximum duration (FF) indicates indefinite dwell for the selected mode. All stack modes below those having a 0 or FF duration are not accessed. The stack can be interrupted and reset to the top by the *HV\_OFF* command. Proper operation of the instrument requires that high voltage be enabled, and this is done with the *HV\_ON* command. It is necessary to ensure that the proper precautions are taken before issuing this command during ground testing and after launch.

In addition to regular Housekeeping data, which is placed in telemetry every second, diagnostic commands that return specific information about the state of the instrument are available through the *DIAG\_SEL* command. The *MAP\_PXL* command which removes selected pixels from consideration in the peak search, is also available, as is the *UPLOAD\_QUAD* command, which facilitates the uploading of new adaptive quadrature boundaries. The list of DIDM-2 commands is as follows:

- |                         |                       |                           |
|-------------------------|-----------------------|---------------------------|
| (i) <i>HV-ON</i>        | (iv) <i>DIAG_SEL</i>  | (vii) <i>CONFIG_DEF</i>   |
| (ii) <i>HV-OFF</i>      | (v) <i>MAP_PXL_A</i>  | (viii) <i>UPLOAD_QUAD</i> |
| (iii) <i>CONFIG_SEL</i> | (vi) <i>MAP_PXL_B</i> |                           |

It is a CHAMP requirement that all *commands* be preceded by the 4 byte header in Table 1. The

TABLE 1: COMMAND HEADER
-------------------------

byte definition and description of each command follows.

CP_seqNo	CP_ChkVal	CP_Dlen						
Packet sequence number	Check value	Not used (b <sub>15</sub> ; MSB)	Not used (b <sub>14</sub> )	Not used (b <sub>13</sub> )	Not used (b <sub>12</sub> )	Not used (b <sub>11</sub> )	Not used (b <sub>10</sub> )	Data field length (b <sub>9</sub> .. b <sub>0</sub> )
1 byte	1 byte	1 bit	1 bit	1 bit	1 bit	1 bit	1bit	10 bit

- Notes** (i) *Data field length* indicates # bytes for following command.  
(ii) *CP\_ChkVal* is applied to *CP\_Dlen* plus *Data field* of the command.

### 2.3.6 Telemetry Format

The instrument's output telemetry format consists of: (i) Communication Packet header (packet sequence number check value, data field length information and flags); followed by (ii) Status packet (6 bytes); (iii) Planar Langmuir Probe (PLP) packet (8 bytes); (iv) a variable number of Drift Meter (DM) packets (10 bytes/packet); (v) a variable number of Retarding Potential Analyzer (RPA) packets (18 bytes/packet); (vi) a variable number of Image packets (64 or 21 bytes/packet); and (vii) a command echo transmitted in conjunction with the receipt of a command. Once per minute four house keeping parameters (1 byte each) and a Configuration packet (11 bytes) are included between the Communication Packet header and the rest of the telemetry. When commanded to do so, DIDM will also add 64 bytes/sec of return data for a one minute period, in return data packets (64 bytes each).

It is a CHAMP requirement that all telemetry be preceded by the 4 byte header in Table 2. The byte definition and description of the telemetry structure follows.

TABLE 2: TELEMETRY HEADER

CP_seqNo	CP_ChkVal	CP_Dlen						
Packet sequence number	Check value	H/K Flag (b <sub>15</sub> ; MSB)	Not used (b <sub>14</sub> )	Not used (b <sub>13</sub> )	Not used (b <sub>12</sub> )	Not used (b <sub>11</sub> )	Not used (b <sub>10</sub> )	Data field length (b <sub>9</sub> .. b <sub>0</sub> )
1 byte	1 byte	1 bit	1 bit	1 bit	1 bit	1 bit	1bit	10 bit

**Notes** (i) *Packet sequence number*: This byte is generated by DIDM and forms the LSB of the two byte DIDM frame counter. The MSB is returned in the *Status Packet* described in the telemetry structure.  
(ii) *H/K flag*: bit b<sub>15</sub> shall indicate whether the *CP\_Data field* contains any *H/K data* (b<sub>15</sub> = 1) or not (b<sub>15</sub> = 0).

#### 2.3.6.1 Overall Telemetry Structure

Once per minute DIDM will output H/K and science data in the telemetry format shown in Table 3.

TABLE 3: H/K & SCIENCE DATA TELEMETRY FORMAT

Header	Temperature Monitor	High Voltage Monitor	Low Voltage (+5V) monitor	Mode Stack Monitor	DIDM Configuration	
4 bytes	1 byte	1 byte	1 byte	1 byte	11 bytes	

	Status packet	0-1 PLP packet	0-16 DM packets (sensor A and or B)	0-2 RPA packets (sensor A and or B)	0-8 Image packets (sensor A and or B)	Command Echo
	6 bytes	1 byte header + 8 bytes/ packet	1 byte header + 10 bytes/packet	1 byte header + 18 bytes/packet	1 byte header + 64 or 21 bytes/packet	n bytes

Fifty-nine times per minute DIDM will output science data only, the telemetry format shown in Table 4.

TABLE 4: SCIENCE DATA TELEMETRY FORMAT

Header	Status packet	0-1 PLP packet	0-16 DM packets (sensor A and or B)	0-2 RPA packets (sensor A and or B)	0-8 Image packets (sensor A and or B)	Command Echo
4 bytes	6 bytes	1 byte header + 8 bytes/packet	1 byte header + 10 bytes/packet	1 byte header + 18 bytes/packet	1 byte header + 64 or 21 bytes/packet	n bytes

**Notes** (i) When science packets are taken from both sensors, the data stream will be telemetered with a science header for sensor A, followed by DM, RPA, or Image data from that sensor. Next will be a science header for sensor B, followed by DM, RPA, or Image data from that sensor. There is always a unique science header preceding each group of science packets. The possible choices are: *PLP, DM A, DM B, RPA A, RPA B, Image A, Return Data and Image B*.  
(ii) The field *Command Echo* will only be sent in conjunction with the receipt of a command.

#### 2.3.6.2 Housekeeping Data (32 bits) Telemetry Structure

DIDM housekeeping (H/K) data comprises the four byte structure shown in Table 5.

TABLE 5: H/K DATA TELEMETRY FORMAT

	Value	Size	Conversion	Comment
Byte0	TEMPMON	8 bits	Temp (°C) = 0.5767 * Counts - 50.853 0 counts = -51°C 132 counts = 25°C 255 counts = 96°C	Temperature monitor
Byte1	HVMON	8 bits	-19.6 V/count Nominal = -2175.6V ⇒ 111 counts	High voltage monitor
Byte2	LVMON	8 bits	39.2 mV/count Nominal = 5.0 V ⇒ 127 counts	Low voltage (+5V) monitor
Byte3	Mode Stack Monitor	8 bits	1 - FF	Starting with configuration duration and decreasing once per minute following the selection of a specified configuration (FF = ∞)

**Notes** (i) DIDM housekeeping is sent once per minute. The H/K flag in the telemetry header will be set to indicate the presence of housekeeping in the output telemetry.

### 2.3.6.3 Config Data (88 bits) Telemetry Structure

DIDM Configuration (Config) data is comprised of the eleven byte structure shown in Table 6.

TABLE 6: CONFIG DATA TELEMETRY FORMAT

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte 0	Stencil/Image Packet			Accum Rate		DM Sample Rate			DM A mode
Byte 1	Stencil/Image Packet			Accum Rate		DM Sample Rate			DM B mode
Byte 2	RPA Packets		RPA Grounded /ON	Time Offset		RPA Sweep Number			RPA A Configuration
Byte 3	RPA Packets		RPA Grounded /ON	Time Offset		RPA Sweep Number			RPA B Configuration
Byte 4	LP Ref	Range	RPA Voltage Offset						RPA A Offset
Byte 5	LP Ref	Range	RPA Voltage Offset						RPA B Offset
Byte 6	*Mode Stack Conf Lib	*Default SAAQ	Pulser	PLP Sweep		*Bad Pixel Maps Cleared	Wedge Table		Options and Diagnostic flags
Byte 7	S/C Ref	PLP Voltage Offset							PLP Offset (-2.5V ↔ +2.5V)
Byte 8	Current Mode Stack Slot # (0 - F)				Preset or Upd	Configuration ID (A - H)			Configuration Information
Byte 9	*Return SAAQ	*Return Bad Pixel	Spare	Sensor A MCP Gain		Spare	Sensor B MCP Gain		Diagnostic Flags
Byte 10	Time remaining value								Time remaining for existing configuration

**Notes** (i) The RPA Offset voltage values are encoded. The encoding scheme is as follows:

D7: 0 = absolute; 1 = relative offset

D6: 0 = low range; 1 = high range

D5 - D0: offset count

low range offset =  $(\text{count} \times 390/4096) - 2.47V$

high range offset =  $[(4 \times \text{count} + 64) \times 390/4096] - 2.47V$

(ii) The PLP Offset voltage values are encoded. The encoding scheme is as follows:

D7: 0 = absolute; 1 = relative offset

D6-D0: = offset count

Offset =  $39.072mV \times \text{count} - 2.5V$

(iii) \*Diagnostic Flag indicators.

#### 2.3.6.4 Status Packet (48 bits) Telemetry Structure

DIDM Status Packet data is comprised of the six byte structure shown in Table 7.

TABLE 7: STATUS PACKET DATA TELEMETRY FORMAT

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	0	1	0	1	1	0	1	0	Sync1=0x5A
Byte1	1	0	1	0	0	1	0	1	Sync2=0xA5
Byte2	HVON	P4 Sen. B	P3 Sen. B	Early Sync	PLP Sync. Bit	RPA B Sync. Bit	RPA A Sync. Bit	Reset	Sync bits (D3-1)=1 if PLP/RPA sweep just started, (D3-1)=0 all other times
Byte3	P2 Sen. B	P1 Sen. B	P0 Sen. B	P4 Sen. A	P3 Sen. A	P2 Sen. A	P1 Sen. A	P0 Sen. A	Background A/B Page (+ D6-5 Byte2)
Byte 4	Frame Counter MSB							Frame Counter	
Byte 5	PLP Floating Potential							Avg. of 2 most recent measurements	

**Notes** (i) The *Status Packet* is located at the beginning of the DIDM science data.

(ii) It contains a sync word, a status byte, a background pointer for each sensor the Frame Counter MSB and flags to indicate if High Voltage is ON and if DIDM is in a reset condition.

(iii) The background pointer is used to determine the row-column location of background image packets for each sensor (Byte 2 D6-5 & Byte 3 D7-5 for Sensor B, Byte 3 D4-0 for Sensor A). See section 5.9c for additional information on the Background Data Packet Structure.

(iv) The *Frame Counter MSB* is used in conjunction with the *Packet Sequence* number in the *Header* to make a 2 byte frame counter.

(v) The *Reset* flag is essentially a re-boot indicator. It indicates that instrument has been power cycled. It is set to 1 on initialization and remains in that state until DIDM receives a command from the ground.

(vi) The *PLP Floating Potential* values are encoded. The encoding scheme is as follows:

$$FP = 39.072mV \cdot count - 5V$$

#### 2.3.6.5 Science Header (8 bits) Telemetry Structure

There are three different Science Headers, one each for DM and RPA, Image, and PLP data. Each Header is comprised of the one byte structure shown in Table 8a, 8b and 8c, respectively.

TABLE 8a: SCIENCE HEADER FORMAT – DM & RPA DATA

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID			Length (1-16 packets)					D7-D5 = 000: DM A = 001: DM B = 010: RPA A = 011: RPA B

TABLE 8b: SCIENCE HEADER FORMAT – IMAGE DATA

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID D7-D5 = 100: Image A = 101: Image B			Image ID D4-D3 = 00: Small = 01: Large = 10: Background = 11: Return Data		Length (1-16 packets) D2-D0 = 001: 1 packet = 010: 2 packets = 011: 4 packets = 100: 8 packets = 101: 16 packets			

TABLE 8c: SCIENCE HEADER FORMAT – PLP DATA

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	Report ID			PLP Packet ID					D7-D5 = 110 PLP D4-D0 = sequence number running from 0 -14

**Notes** (i) The *Science Header* identifies the packets immediately following it as either *DM*, *RPA*, *Image*, or *PLP* packets. The specific sensor associated with a *DM*, *RPA*, or *Image* packet is also defined in the science header. Thus if both sensors are reporting *DM* data, a unique science header will appear first for *Sensor A* followed by a variable number of *DM* packets for that sensor, then another unique science header will appear for *Sensor B* followed by a variable number of *DM* packets for that sensor. The same holds true for *RPA* and *Image* packets depending on the configuration that DIDM is operating in.

(ii) The Length field announces the number of packets ( $\leq 16$ ) that will follow a particular science header. *DM* and *RPA* science headers are similar in structure with 3 bits for Report ID and 5 bits for the length field.

(iii) If the Report ID indicates *Image*, then the Length field is subdivided into 2 bits for Image ID and 3 bits for length (maximum of 16 image packets). *Image* packets can be defined as *small*, *large*, *background image*, or *return data* packets.

(iv) If the Report ID indicates *PLP*, then there is no Length field because all PLP packets are 8 bytes. The remaining bits in the PLP header field are used to identify specific PLP packet numbers.

### 2.3.6.6 Langmuir Probe Packet (64 bits) Telemetry Structure

DIDM Langmuir Probe Packet data is comprised of the sixty four byte structure shown in Table 9.

TABLE 9: LANGMUIR PROBE PACKET DATA TELEMETRY FORMAT

#### PLP Data Packets #0-7

	Descriptor	Comment
Byte0	ELEC 4*(Packet #)+1 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+1
Byte1	ELEC 4*(Packet #)+1 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+1
Byte2	ELEC 4*(Packet #)+2 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+2
Byte3	ELEC 4*(Packet #)+2 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+2
Byte4	ELEC 4*(Packet #)+3 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+3
Byte5	ELEC 4*(Packet #)+3 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+3
Byte6	ELEC 4*(Packet #)+4 LSB	LSB of 16 bit Electrometer sample 4*(Packet #)+4
Byte7	ELEC 4*(Packet #)+4 MSB	MSB of 16 bit Electrometer sample 4*(Packet #)+4

*Example: Packet # 0, Byte 0 contains the LSB for Electrometer sample 1 (i.e.  $4*0+1 = 1$ ) while Packet #7, Byte 7 contains the MSB for Electrometer sample 32 (i.e.  $4*7+4 = 32$ )*

#### PLP data Packets #8-14

	Descriptor	Comment
Byte0	FP 8*(Packet#-8)+1	8 bit Floating Potential sample 8*(Packet#-8)+1
Byte1	FP 8*(Packet#-8)+2	8 bit Floating Potential sample 8*(Packet#-8)+2
Byte2	FP 8*(Packet#-8)+3	8 bit Floating Potential sample 8*(Packet#-8)+3
Byte3	FP 8*(Packet#-8)+4	8 bit Floating Potential sample 8*(Packet#-8)+4
Byte4	FP 8*(Packet#-8)+5	8 bit Floating Potential sample 8*(Packet#-8)+5
Byte5	FP 8*(Packet#-8)+6	8 bit Floating Potential sample 8*(Packet#-8)+6
Byte6	FP 8*(Packet#-8)+7	8 bit Floating Potential sample 8*(Packet#-8)+7
Byte7	FP 8*(Packet#-8)+8	8 bit Floating Potential sample 8*(Packet#-8)+8

*Example: Packet # 0, Byte 0 contains the Floating Potential sample 1 (i.e.  $8*[8-8]+1 = 1$ ) while Packet #14, Byte 7 contains the Floating Potential sample 56 (i.e.  $8*[14-8]+8 = 56$ )*

**Notes** (i) The PLP data is located at the beginning of the DIDM science data. The field length is always 8 bytes.

(ii) There are two types of PLP packets: *Electrometer* samples and *Floating Potential* samples. The first 8 packets in a sequence contain a total of 32 16-bit *Electrometer* samples broken into least significant and most significant bytes. The following 7 packets in the sequence contain a total of 56 8-bit *Floating Potential* samples

(iii) *Electrometer* and *Floating Potential* packets are only sent when the PLP is switched ON in the *Config\_Def* command. *Floating Potential* measurements are continuously made while the instrument is powered and are used to determine RPA voltage offsets if required. However, this data appears in the *Status Packet* only. PLP packets are sent once per second in a sequence of 15 packets that correspond to the 15 second PLP acquisition cycle. The PLP electrometer takes an I-V curve for 1 second, every 15 seconds. The floating potential is sampled during the other 14 seconds, at a rate of 4 samples per

second (56 samples per 14 seconds). It takes 8 seconds to telemeter the *Electrometer* data, and the remaining 7 seconds are used to telemeter the *Floating Potential* data.

(iv) The *PLP Electrometer* packet values are encoded. The encoding scheme is as follows:.

D15 - D14 unused

D13 - D12 Range bits

D11 - D0 PLP counts

Range Range bits Count <2048 (+curr) Count >=2048 (-curr)

(D13 - D12) I(Amps) = I(Amps) =

+/- 5mA 11 count\*2.441E-6 (count-4096)\*2.441E-6

+/- 156uA 01 count\*7.629E-8 (count-4096)\*7.629E-8

+/- 4.88uA 10 count\*2.384E-9 (count-4096)\*2.384E-9

+/- 153nA 00 count\*7.451E-11 (count-4096)\*7.451E-11

(v) The *PLP Floating Potential* values are encoded. The encoding scheme is as follows:.

FP = 19.53mV\*count-2.5V

### 2.3.6.7 Drift Meter Packet (80 bits) Telemetry Structure

DIDM Drift Meter Packet data is comprised of the eighty bits structure shown in Table 10.

TABLE 10: DRIFT METER PACKET DATA TELEMETRY FORMAT

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	SAAQ S8	PC6	PC5	PC4	PC3	PC2	PC1	PC0	Peak Column (0-127)
Byte1	MR9	MR8	MC9	MC8	PR3	PR2	PR1	PR0	Peak Row (0-15) + Moment MS bits
Byte2	MC7	MC6	MC5	MC4	MC3	MC2	MC1	MC0	SAAQ Column moment LSB
Byte3	MR7	MR6	MR5	MR4	MR3	MR2	MR1	MR0	SAAQ Row moment LSB
Byte4	QCA7	QCA6	QCA5	QCA4	QCA3	QCA2	QCA1	QCA0	Fixed Quadrant A LSB
Byte5	QCB7	QCB6	QCB5	QCB4	QCB3	QCB2	QCB1	QCB0	Fixed Quadrant B LSB
Byte6	QCC7	QCC6	QCC5	QCC4	QCC3	QCC2	QCC1	QCC0	Fixed Quadrant C LSB
Byte7	QCD7	QCD6	QCD5	QCD4	QCD3	QCD2	QCD1	QCD0	Fixed Quadrant D LSB
Byte8	QCD9	QCD8	QCC9	QCC8	QCB9	QCB8	QCA9	QCA8	Fixed Quadrant A-D MS bits
Byte9	SAAQ S7	SAAQ S6	SAAQ S5	SAAQ S4	SAAQ S3	SAAQ S2	SAAQ S1	SAAQ S0	SAAQ Sum Byte 9 D7-0 + Byte 0 D7

**Notes** (i) The Drift Meter packet contains centroid and quadrature information for one image from one sensor. There is a one-to-one correspondence between the number of DM images per second (i.e. DM mode) and the number of DM packets in the telemetry.

(ii) Each packet contains the following:

- location of the image peak (defined by Peak Column [PC] in 7 bits, and Peak Row [PR] in 4 bits).
- the two moments calculated from the Synthetic Aperture Adaptive Quadrature (SAAQ) boundary. (Moment Column [MC] & Moment Row [MR] in 10 bits each).
- the four Quadrants Counts (QCA, QCB, QCC, QCD) from the column quadrature of the pixel map (10 bits each, log compressed)
- the estimated SAAQ sum (SAAQ-S in 9 bits).



(iii) *Column Quadrature* of the anode is as shown in Figure 8, where both the physical division of the anode space (Figure 8a) as well as, the equivalent for the pixel array map (Figure 8b), are shown.

(iv) For the *SAAQ Column (MC)* and *Row (MR)* Moments data, the following apply.

$D9$  = ratio "sign" bit  
 $D8-D0$  = ratio counts  
 Moment = counts/512  
 = -counts/512 when  $D9$  bit is set

(v) Based on the illustration in Figure 9, the SAAQ moments are calculated as follows:

	$D9=0$	$D9=1$
Column Moment	$\frac{1+2}{3+4}$	$\frac{3+4}{1+2}$
Row Moment	$\frac{1+4}{2+3}$	$\frac{2+3}{1+4}$

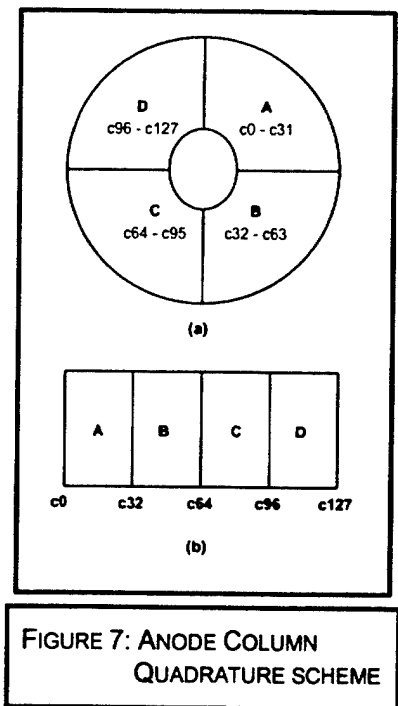
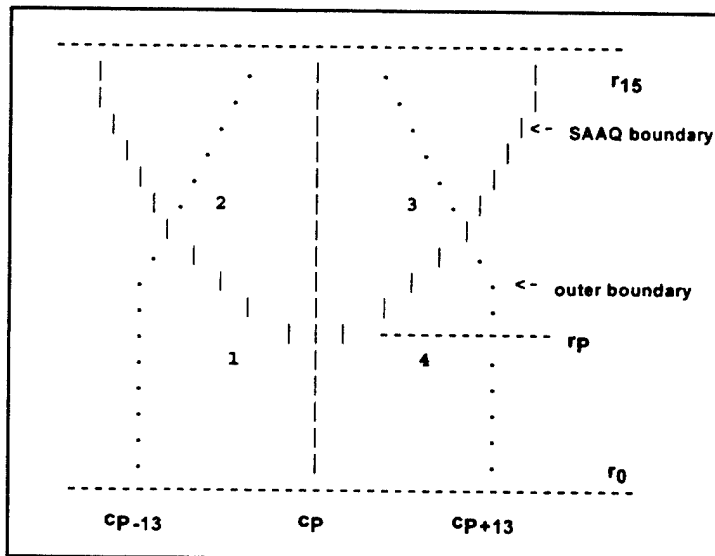


FIGURE 7: ANODE COLUMN QUADRATURE SCHEME

FIGURE 8: SAAQ QUADRATURE SCHEME

Where  $rp$  and  $cp$  are the row and column coordinates respectively for the pixel with the highest number of counts (centroid), and the numbers 1, 2, 3, 4 represent the quadrature designations for the SAAQ (note that anode quadratures are designated with letters A, B, C, D to avoid confusion). Moments are calculated from the sum total of counts in the quadrants.

(vi) The *Drift Meter* packet values are encoded. The encoding schemes are as follows:.

For *Quadrant Counts (QCA, QCB, QCC, QCD)*  $\Rightarrow$  3-7 log compression scheme defined as follows:

scheme	total #bits	exponent bits	range	mantissa bits	range	uncompressed counts =
3-7	10	D9-D7	0-7	D6-D0	0-127	$(2^{\text{exponent}}) * (\text{mantissa} + 128) - 128$

For *SAAQ Sum (SAAQ-S)*  $\Rightarrow$  4-5 log compression scheme defined as follows:

scheme	total #bits	exponent bits	range	mantissa bits	range	uncompressed counts =
4-5	9	D8-D5	0-15	D4-D0	0-31	$(2^{\text{exponent}}) * (\text{mantissa} + 32) - 32$

### 2.3.6.8 RPA Packet (144 bits) Telemetry Structure

DIDM RPA Packet data comprises the one hundred forty four byte structure shown in Table 11.

TABLE 11: RPA PACKET DATA TELEMETRY FORMAT

	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	Comment
Byte0	R1-7	R1-6	R1-5	R1-4	R1-3	R1-2	R1-1	R1-0	RPA sample 1 LSB
Byte1	R2-7	R2-6	R2-5	R2-4	R2-3	R2-2	R2-1	R2-0	RPA sample 2 LSB
Byte2	R3-7	R3-6	R3-5	R3-4	R3-3	R3-2	R3-1	R3-0	RPA sample 3 LSB
Byte3	R4-7	R4-6	R4-5	R4-4	R4-3	R4-2	R4-1	R4-0	RPA sample 4 LSB
Byte4	R4-9	R4-8	R3-9	R3-8	R2-9	R2-8	R1-9	R1-8	RPA 1-4 MS bits
Byte5	R5-7	R5-6	R5-5	R5-4	R5-3	R5-2	R5-1	R5-0	RPA sample 5 LSB
Byte6	R6-7	R6-6	R6-5	R6-4	R6-3	R6-2	R6-1	R6-0	RPA sample 6 LSB
Byte7	R7-7	R7-6	R7-5	R7-4	R7-3	R7-2	R7-1	R7-0	RPA sample 7 LSB
Byte8	R8-7	R8-6	R8-5	R8-4	R8-3	R8-2	R8-1	R8-0	RPA sample 8 LSB
Byte9	R8-9	R8-8	R7-9	R7-8	R6-9	R6-8	R5-9	R5-8	RPA 5-8 MS bits
Byte10	G1-7	G1-6	G1-5	G1-4	G1-3	G1-2	G1-1	G1-0	Gate sample 1 LSB
Byte11	G2-7	G2-6	G2-5	G2-4	G2-3	G2-2	G2-1	G2-0	Gate sample 2 LSB
Byte12	G3-7	G3-6	G3-5	G3-4	G3-3	G3-2	G3-1	G3-0	Gate sample 3 LSB
Byte13	G4-7	G4-6	G4-5	G4-4	G4-3	G4-2	G4-1	G4-0	Gate sample 4 LSB
Byte14	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	G5-7	Gate sample 5 LSB
Byte15	G6-7	G6-6	G6-5	G6-4	G6-3	G6-2	G6-1	G6-0	Gate sample 6 LSB
Byte16	G7-7	G7-6	G7-5	G7-4	G7-3	G7-2	G7-1	G7-0	Gate sample 7 LSB
Byte17	G8-7	G8-6	G8-5	G8-4	G8-3	G8-2	G8-1	G8-0	Gate sample 8 LSB

- Notes**
- (i) The RPA packet contains 8 RPA count samples (10 bits each, log compressed) and 8 corresponding gate count samples (8-bits each, log-compressed.).
  - (ii) Depending on RPA mode, there will be 0 RPA packets (no RPA), 1 RPA packet (RPA=8 Hz) or 2 RPA packets (RPA=16 Hz) in the telemetry per active RPA (i.e. both sensors @ 16 Hz = 4 packets).
  - (iii) The RPA packet values are encoded. The encoding schemes are as follows:

For RPA Counts  $\Rightarrow$  4-6 log compression scheme defined as follows:

scheme	total #bits	exponent bits	range	mantissa bits	range	uncompressed counts =
4-6	10	D9-D6	0-15	D5-D0	0-63	$(2^{\text{exponent}}) * (\text{mantissa} + 64) - 64$

For Gate Counts  $\Rightarrow$  3-5 log compression scheme defined as follows:

scheme	total #bits	exponent bits	range	mantissa bits	range	uncompressed counts =
3-5	8	D7-D5	0-7	D4-D0	0-31	$(2^{\text{exponent}}) * (\text{mantissa} + 32) - 32$

### 2.3.6.9 Image Packet Telemetry Structure (168 or 512 bits, depending on DM Mode)

Image packets contain a subset of the pixel map from either Sensor A or Sensor B. They are constructed in one of four distinct formats described as: Small Stencil, Large Stencil, Background and Return. Background packets sample the entire pixel array, and transmit the data at the specified rate, with 32 background packets required to generate an entire array. The format of each image packet follows.

#### 2.3.6.9a Small Stencil Packet Structure

The *Small Stencil* Image Packet data is comprised of the 21byte structure shown in Table 12.

TABLE 12: SMALL STENCIL PACKET DATA FORMAT

Byte0	Peak Column
Byte1	(Row 0, Column Peak) pixel value, log compressed
Byte2	(Row 1, Column Peak pixel value, log compressed
:	:
:	:
Byte14	(Row 13, Column Peak) pixel value, log compressed
Byte15	(Row 14, Column Peak) pixel value, log compressed
Byte16	(Row 15, Column Peak) pixel value, log compressed
Byte17	(Row 0, Column Peak+64) pixel value, log compressed
Byte18	(Row 1, Column Peak+64) pixel value, log compressed
Byte19	(Row 2, Column Peak+64) pixel value, log compressed
Byte20	(Row 3, Column Peak+64) pixel value, log compressed

- Notes** (i) The *Small Stencil* contains the value for each of the 16 pixel rows at the *peak column* location, and the first 4 rows of pixel data at the column directly opposite the peak.
- (ii) The *Small Stencil* values are encoded. The encoding scheme is as follows:

For *Small Stencil*  $\Rightarrow$  3-5 log compression scheme defined as follows:

scheme	total #bits	exponent bits	range	mantissa bits	range	uncompressed counts =
3-5	8	D7-D5	0-7	D4-D0	0-31	$(2^{\text{exponent}}) * (\text{mantissa} + 32) - 32$

### 2.3.6.9b Return Data Packet Structure

During the one-minute period in which the *Return Data* is active, one *Return Data* type image packet is inserted in each one second telemetry frame, for a total of 60 packets. A full set of return data is completed in 30 seconds, allowing the same information to be transmitted twice and thereby minimize the impact of data dropouts. Packet numbers are referenced with respect to the data frame containing the Configuration Packet, which indicates the active return data; i.e. packet numbers correspond to the number of seconds since the *Return Data* bit went high. No indexing is contained in the return data packets. The contents of the 64 byte Return Data Image Packets vary, depending on the packet number. The contents of the 60 packets returned are indicated in Table 13..

Packets 1-16, 31-46 : SAAQ Boundaries for Peak Rows 0-15

TABLE 13: RETURN DATA IMAGE PACKETS 1 - 16, 31 - 46 FORMAT

Byte0	Boundary "A", Delta Column for Row 0
Byte1	Boundary "A", Length for Row 0
Byte2	Boundary "A", Delta Column for Row 1
Byte3	Boundary "A", Length for Row 1
:	:
:	:
Byte28	Boundary "A", Delta Column for Row 14
Byte29	Boundary "A", Length for Row 14
Byte30	Boundary "A", Delta Column for Row 15
Byte31	Boundary "A", Length for Row 15
Byte32	Boundary "B", Delta Column for Row 0
Byte33	Boundary "B", Length for Row 0
Byte34	Boundary "B", Delta Column for Row 1
Byte35	Boundary "B", Length for Row 1
:	:
:	:
Byte60	Boundary "B", Delta Column for Row 14
Byte61	Boundary "B", Length for Row 14
Byte62	Boundary "B", Delta Column for Row 15
Byte63	Boundary "B", Length for Row 15

**Notes** (i) Each 64-byte packet defines the row-level boundaries for the SAAQ regions for one peak row. The boundaries for quadrature regions A and B only are specified, where the boundaries for regions D and C are implied to be respective mirror images about the peak column.

#### 2.3.6.10 Command Echo Packet Telemetry Structure (24, 40, 88 or 96 bits)

For one second only, *Command Echo* packets appears in telemetry immediately following the receipt of a good command. Bad commands are counted and returned only in *Return Data Packets 17 & 37*. A bad command will not generate a *Command Echo* packet. The *Command Echo* packet data comprises either 3, 5, 11 or 12 bytes depending on the command being echoed. The packet structure shown in Table 14.

TABLE 14: COMMAND ECHO PACKET DATA FORMAT

Field No.	Name	Type	Size
Byte0	Report ID	HEX	8 bits
Byte1	CP_Seq No	HEX	8 bits
Byte2	Command_ID	HEX	8 bits
Byte 3	Parameter	HEX	8 bits
:	:	:	:
:	:	:	:
Byte 11	Parameter	HEX	8 bits

- Notes**
- (i) Bits D7-D5 = 111 of the report ID identify the packet as a command echo packet and bits D4 - D0 specify the number of parameters associated with the echoed command. The possibilities are 0, 2, 8, or 9.
  - (ii) Byte 1 is an echo of the CP\_Seq No. It is the associated communication packet number for the sent command.
  - (iii) The Command ID is the unique identifier for the command that has been sent.

### 2.3.7 RPA Sweeps

There are seven different RPA sweeps profiles that can be applied by command, to DIDM-2. Table 15 lists the step number and corresponding voltage for each of the seven sweeps. Profiles of the sweeps as they are implemented, are shown in Figures 10 to 13.

TABLE 15: STEP VOLTAGE FOR RPA SWEEPS

Step No.	RPA SWEEP (Volts)						
	#1	#2	#3	#4	#5	#6	#7
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	4.80	0.00	0.00	2.00	3.80	0.30	0.30
3	1.20	4.00	1.20	3.50	4.80	0.60	0.60
4	4.80	4.80	1.20	4.00	6.00	0.90	0.90
5	0.00	1.20	3.80	4.50	0.00	1.20	1.20
6	4.80	1.20	4.80	5.00	3.80	1.60	1.60
7	1.20	6.00	5.80	5.50	4.80	2.00	2.00
8	4.80	4.80	6.80	6.00	6.00	2.50	2.50
9			6.80			3.00	3.00
10			5.80			3.50	3.66
11			4.80			4.00	4.25
12			3.80			4.50	4.75
13			1.20			5.00	5.25
14			0.60			5.50	5.75
15			0.00			6.00	6.50
16			0.00			7.00	7.25
17							24.00
18							18.00
19							12.00
20							11.00
21							10.25
22							9.50
23							9.00
24							8.50
25							8.00
26							7.25
27							6.50
28							5.75
29							5.25
30							4.75
31							4.25
32							3.75

- Notes** (i) To implement the *RPA grounded* command, the instrument executes an 8 or 16 step sequence (depending on configuration) of 0.0 Volts per step, each second.
- (ii) It is also necessary to specify: *absolute offset & 0 offset*; to execute the command.
- (iii) Interpret the x Hz reference on the following plots to mean x steps per second.

### 2.3.8 PLP Sweeps

There are three different PLP sweep profiles that can be applied by command to DIDM-2. Table 16 lists the step number and corresponding voltage for each sweep. Profiles of the sweeps as they are implemented are shown in Figures 14 to 16.

TABLE 16: STEP VOLTAGE FOR PLP SWEEPS

Step No.	PLP SWEEP (Volts)		
	#1	#2	#3
1	1.770	-2.500	-3.999
2	1.169	-2.026	-2.727
3	0.786	-1.641	-1.824
4	0.540	-1.328	-1.223
5	0.376	-1.074	-0.828
6	0.264	-0.867	-0.559
7	0.183	-0.698	-0.371
8	0.125	-0.562	-0.232
9	0.081	-0.449	-0.115
10	0.046	-0.354	0.000
11	0.022	-0.276	0.132
12	0.005	-0.212	0.308
13	-0.012	-0.156	0.557
14	-0.042	-0.105	0.923
15	-0.076	-0.061	1.475
16	-0.110	-0.020	2.307
17	-0.149	0.020	3.569
18	-0.193	0.061	2.307
19	-0.244	0.105	1.475
20	-0.303	0.156	0.923
21	-0.371	0.212	0.557
22	-0.454	0.276	0.308
23	-0.552	0.354	0.132
24	-0.669	0.449	0.000
25	-0.808	0.562	-0.115
26	-0.979	0.698	-0.232
27	-1.179	0.867	-0.371
28	-1.423	1.074	-0.559
29	-1.714	1.328	-0.828
30	-2.068	1.641	-1.223
31	-2.490	2.026	-1.824
32	-3.000	2.500	-2.727

### 2.3.9 Wedge Tables

There are four different Wedge Tables built into DIDM-2, each of which can be selected by command. They are referred to as Wedge Tables 0, 1, 2 or 3. Wedge Table 0 is the default and Wedge Table 1 is generally referred to as the FWHM table. Wedge Tables 2 and 3 are alternates to Table 0 and these three tables relate the wedge and sum (wedge + strip + z) signals from the anode to a specific row address. The relationship can be represented as follows:

where:

*row* = row address

*W* = wedge signal (volts)

*S* = strip signal (volts)

*Z* = z signal (volts)

$$\boxed{row = \frac{K_{r1} \times W}{\Sigma(W,S,Z) - K_{r2}}}$$

$\Sigma(W,S,Z)$  = Sum of wedge, strip and z signals

$K_{r1}, K_{r2}$  = scale and offset constants respectively, for *r*.

The specific relationship for row address determination for each of the three tables are as follows:

$$\text{Table 0} \Rightarrow row(T0) = Round\left\{\frac{80.1 \times W}{\Sigma(W,S,Z) - 11.6}\right\}$$

$$\text{Table 2} \Rightarrow row(T2) = Round\left\{\frac{65.1 \times W}{\Sigma(W,S,Z) - 7.7}\right\}$$

$$\text{Table 3} \Rightarrow row(T3) = Round\left\{\frac{72.9 \times W}{\Sigma(W,S,Z) - 9.8}\right\}$$

With Wedge Table 1, the usual 16 rows x 128 column array pixel map is reduced to a single column with 16 rows. This is accomplished by summing the counts in each row, for all 128 columns. The instrument output then becomes a spectrogram, showing the radial distribution of events on the anode (and thus the FWHM designation).

### 2.3.10 Strip Table

There is only one relationship for column address determination in the instrument, and it is as follows:

$$Col = 100 \times INT\left\{\frac{S}{\Sigma(W,S,Z) - 9}\right\}$$

where:

$\theta$  = column address

*W* = wedge signal (volts)

*S* = strip signal (volts)

*Z* = z signal (volts)

$\Sigma(W,S,Z)$  = Sum of wedge, strip and z signals



### 2.3.11 SAAQ Boundary & Tables

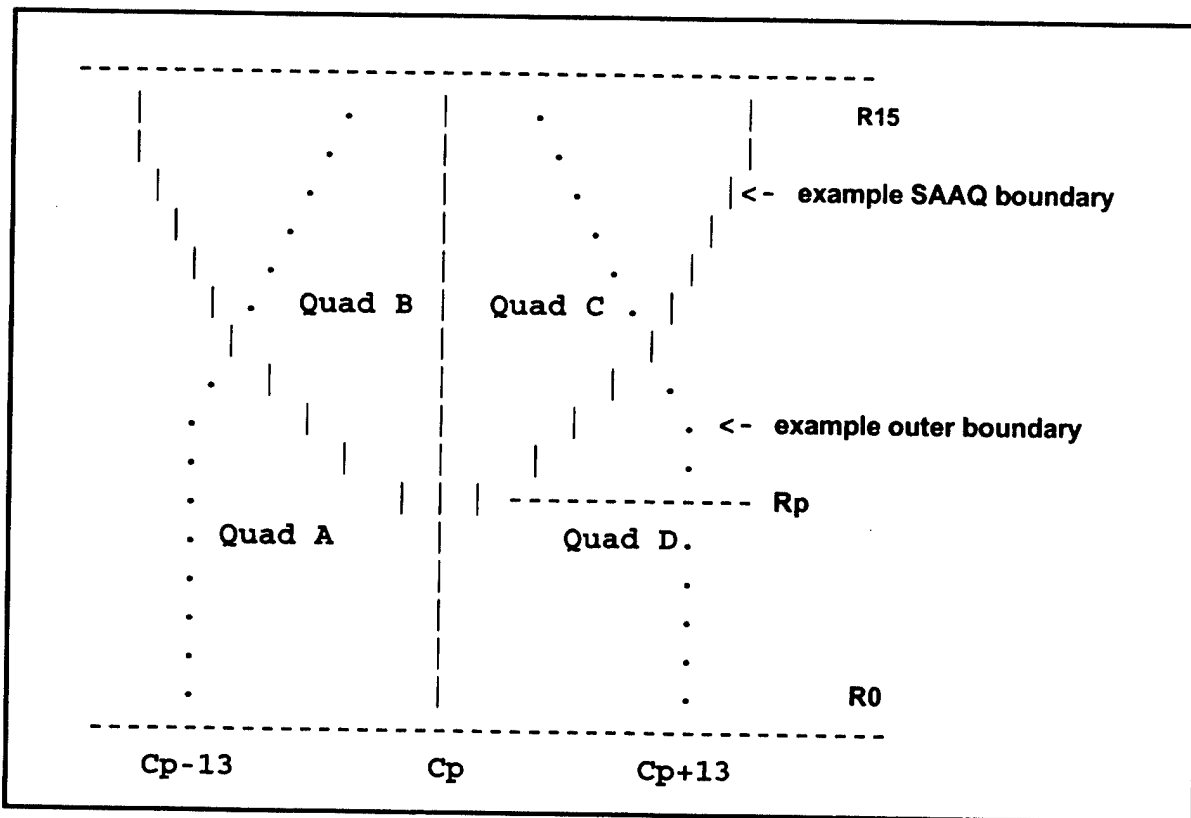


FIGURE 9: SAAQ BOUNDARY ILLUSTRATED

The SAAQ table is actually comprised of sixteen separate tables, each one describing the SAAQ boundary for each of the 16 possible peak rows. The ensemble is illustrated above in Figure 19. For each possible peak row, there are 32 entries: 16 to describe the outer SAAQ boundaries for Quadrant A (mirrored to describe Quadrant D), and 16 to describe the boundaries for Quadrant B (mirrored to describe Quadrant C.). Each entry is two bytes: dC (delta Column) which is the number of columns left of the peak column (Cp) to start the quadrant and L (length) which is the number pixels to the right of column=Cp-dC to add to the quadrant sum.

The illustration above can be described as follows: 5 tables of 32 entries each describing boundaries for peak rows 0 through 5 (this example is for Rp=5). For each entry, the row coordinate is assumed, starting at 0 and going up to 15. Then:

(dC=13,L=13),(13,13),(13,13),(13,13),(13,13),(13,11),(13,8),(13,5),(12,3),(0,0),(0,0),(0,0),  
(0,0),(0,0),(0,0),(0,0). [(x,0) means no pixels for this row]

This describes Quadrant A, and when mirrored about Cp, it also describes Quadrant D. [The SAAQ routine adds 1 to dC for Quadrants C & D so that they won't overlap with quadrants A & B.]

Similarly, Quadrant B (and Quadrant C) would be:

(0,0),(0,0),(0,0),(0,0),(0,0),(2,2),(5,5),(8,8),(10,10),(9,9),(8,8),(7,7),(6,6),(5,5),(4,4),(3,3)

Note that for a table in byte format, the ordering is reversed, i.e. L,dC,L,dC...

### 2.3.12 Default Configurations and Mode Stack

The Mode Stack in DIDM-2 accommodates eight entries. The default configurations in each entry and the order in which they appear on power-up are shown in Table 17.

TABLE 17: DEFAULT MODE STACK AND CONFIGURATIONS

	Index	Duration (mins)	DM A		DM B		RPA				PLP	
			Image	Rate	Image	Rate	A Config	B Config	A Offset	B Offset	Sweep/ Offset	Wedge Table
Preset A	1	15	none	4 samples per sec	none	none	none, grounded	16Hz, sweep #6	0V, absolute	0V, absolute	none, 0V, absolute	0
Preset B	2	15	small stencil	2 samples per sec	none	none	none, grounded	8Hz, sweep #4	0V, absolute	0V, absolute	sweep #1, 0V, absolute	0
Preset C	3	15	none	4 samples per sec	none	4 samples per sec	none, grounded	8Hz, sweep #2	0V, absolute	0V, absolute	sweep #1, 0V, absolute	0
Preset D	4	15	none	8 samples per sec	none	none	none, grounded	16Hz, sweep #5	0V, absolute	0V, relative	none, 0V, absolute	0
Preset E	5	15	large stencil	4 samples per sec	none	none	none, grounded	16Hz, sweep #7	0V, absolute	0V, relative	sweep #1, 0V, absolute	0
Preset F	6	15	none	4 samples per sec	none	4 samples per sec	8Hz, sweep #2	8Hz, sweep #2, Toff=4	0V, relative	0V, relative	none, 0V, absolute	0
Preset G	7	15	4 bkgnd per sec	4 samples per sec	none	none	none, grounded	16Hz, sweep #6	0V, absolute	0V, absolute	none, 0V, absolute	0
Preset H	8	15	none	8 samples per sec	none	8 samples per sec	8Hz, sweep #1	16Hz, sweep #2, Toff=2	0V, relative	0V, relative	none, 0V, absolute	0

**Notes** (i) it has been observed that if the HV\_OFF command is sent at a time coincident with a mode stack change, then the mode stack index and sequence will jump to the last entry in the stack. If this entry has a defined duration of 0 sec, the configuration will be executed for 1 minute anyway.

### **3. TASK #2—DATA ANALYSIS EFFORTS**

#### **3.1 Program Definition**

The objective of this task is to analyze the interactions between rockets and spacecraft with the space environment to advance the understanding of dynamic space plasma effects. Efforts have been directed toward the analysis of data from the Tethered Satellite Systems flights (TSS-1 and TSS-1R), and the Space Wave Interactions with Space Plasmas Experiment (SWIPE) flown on the Observation of Electric-field Distributions in Ionospheric Plasma: a Unique Solution (OEDIPUS-C) mission and most recently, the data from the LAngmuir TURbulence (LATUR) rocket mission.

The work is concerned with characterizing electron beam-space plasma interactions and the dynamic I-V particulars of a magnetized plasma. Such knowledge of the space plasma environment and of its interactions with spacecraft, is critical to the design of future platforms in space.

#### **3.2 Summary of Activities**

Work continued on the analysis of the OEDIPUS-C and SPREE datasets throughout most of the report period. Previous efforts were heavily focused on exploiting particular portions of the OEDIPUS-C data (the electron count spectrum and to a lesser extent the sub-millisecond response functions after the transmitter pulse), in particular. No use has thus far been made of the third dataset - the detailed MHz buncher data. Several periods of highly gyro-bunched electrons, with highly non-linear (non sinusoidal) modulations and bunching periods close to the transmitter frequency have been previously noted but not used. This was due in part to the fact that the OEDIPUS-C EPI data display program has always experienced problems synchronizing the three datasets, i.e. (i) spectra; (ii) millisecond TX response delay, and (iii) HF buncher (MegaHertz autocorrelator), which the instrument provides. A new program was written and verified for OEDIPUS-C EPI data, which displays the three datasets in parallel, so that the synchronizing problems can be fully understood. When completed, it would make it possible to either generate an algorithm to illiminate the problem, or at minimum, provide the user with unambiguous knowledge of which datasets correspond to which. This is particularly important for exploiting the MegaHertz dataset.

In final summary of this effort, the consultant (Professor M. Paul Gough, of the Space Science Center at the University of Sussex, U.K.) who was the principal participant in these activities, states that the large number of scientific publications from TSS-1, TSS-1R and OEDIPUS-C clearly shows that high geometric factor particle spectrometers with wide fields of view, combined with the particle correlation technique, provide a powerful diagnostic of space plasma processes. In particular, this combination provides a unique view of the microphysics occurring during active plasma experiments involving either an artificial electron beam, as in the case of TSS-1/TSS-1R and OEDIPUS-C, where a transmitter provided artificial source of waves, or transmitter heating of ambient ionospheric plasma, as in the case of LaTur. The overall high scientific return from these projects indicates that it would be mutually profitable to continue similar collaborations in the future. A listing of articles published in scientific journals as a result of this work is presented on the following page.

### 3.2.1 Publications in Scientific Journals resulting from work accomplished on Task #2

*Particle Modulations at kHz and MHz measured by the Shuttle Potential and Return Electron Experiment (SPREE) during STS-46;* M.P.Gough, D.A.Hardy, M.R.Oberhardt, W.J.Burke, L.C.Gentile, B.McNeil, K.Bounar, D.C.Thompson, W.J.Raitt, EOS, Trans. American Geophysical Union, 75,499, 1994

*MegaHertz Electron Modulations Measured by SPREE during DC Electron Gun Operations on STS-46;* M.P.Gough, M.R.Oberhardt, D.A.Hardy, B.McNeil, K.Bounar, D.C.Thompson, W.J.Raitt J.Geophys. Res., 100, 21561-21575,1995.ISSN-0148-0227

*Early results from the particle correlators on OEDIPUS-C;* M.P.Gough, D.A.Hardy, H.G.James, UK MIST meeting November 1995 Q. J. R. Astron. Soc,37, 307-313, 1996.

*Particle Correlation Techniques;* M.P.Gough Signal Processing Techniques with Space Radio and Plasma wave Data session of the International Union of Radio Science (URSI) Lille, August,1996.

*Low Frequency Electron Modulations Observed during DC Electron Beam Emissions in the Deployed Phase of TSS-1;* C.Y.Huang, L.C.Gentile, D.A.Hardy, W.J.Burke, W.J.Raitt, D.C.Thompson, M.P.Gough American Geophysics Union, Baltimore, May 1996

*Observation of Electron Heating During the Oedipus-C Sounding Rocket Experiment;* D.A.Hardy, D.Olsen, W.J.Burke, G.Ginet, M.P.Gough, C.Huang, H.G.James American Geophysics Union, Baltimore, May 1996

*Heating and low-frequency modulation of electrons observed during electron beam operations on TSS-1;* M.P.Gough, D.A.Hardy, W.J.Burke, M.R.Oberhardt, L.C.Gentile, C.Y.Huang, D.L.Cooke, W.J.Raitt, D.C.Thompson, W.McNeil, K.Bounar, J.Geophysical Research, 102, pp17335-17357, 1997

*Relation of Observed Electron Modulation Frequencies to Plasma Characteristic Frequencies during DC Electron Beam emissions on STS-75;* M.P.Gough, D.A.Hardy, W.J.burke, D.C.Thompson, W.J.Raitt. UK MIST meeting November 1996, Abstract in Astronomy and Geophysics, J. R. Astron. Soc,Vol 38, 19, 1997.

*Relationships between Mhz Modulations of Electron Beams detected during TSS 1-R and Whistler Waves observed during Spacelab 2;* C.Y.Huang, W.J.Burke, M.P.Gough, L.C.Gentile, D.A.Hardy, D.G.Olson, Union of Radio Scientists International meeting Montreal, 1997

*Electron Acceleration and Trapping during the OEDIPUS C Sounding Rocket Experiment;* W.J.Burke, D.A.Hardy, M.P.Gough, C.Y.Huang, L.C.Gentile, D.G.Olson, Union of Radio Scientists International meeting Montreal, 1997

*MegaHertz electron modulations observed during TSS-1R beam emission experiments;* M.P.Gough, W.J.Burke, D.A.Hardy, C.Y.Huang,L.C.Gentile, A.G.Rubin, M.R.Oberhardt, D.C.Thompson, W.J.Raitt, Geophysics Res. Lett. Vol 25, pp 441-444, 1998

*SPREE measurements of wave-particle interactions generated by the electron guns on TSS-1 and TSS-1R;* M.P.Gough, D.A.Hardy, M.R.Oberhardt, W.J.Burke, L.C.Gentile, D.C.Thompson, W.J.Raitt Adv. Space Res., Vol 21, No5, pp 729-733, 1998

*First results from the particle correlators on the OEDIPUS-C sounding rocket;* M.P.Gough, D.A.Hardy, H.G.James, Adv. Space Res. , Vol 21, No 5, pp 705-708, 1998

*Cerenkov emissions of ion acoustic like waves generated by electron beams emitted during TSS 1R;* C.Y.Huang, W.J.Burke, D.A.Hardy, M.P.Gough, D.G.Olson, L.C.Gentile, B.E.Gilchrist, C.Bonifazi, W.J.Raitt, D.C.Thompson, Geophysics Res.Lett., Vol 25, pp 721-724, 1998

*Particle Correlator Instruments in Space:Performance; Limitations,Successes,and the Future.* M.P.Gough Measurement Techniques in Space Plasmas: Particles, American Geophysics Union, Geophysical Monograph 102, 1998.

#### **4. TASK #3—LaTUR EFFORTS**

##### **4.1 Program Definition**

The objective of this task was to pursue the development of techniques to design and build miniaturized, low power and considerably capable space experiment instrumentation. With the LaTUR mission concluded, all work on this task has ended.